How to Buy an Energy-Efficient Water-Cooled Electric Chiller

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Federal Supply Source:

- General Services Administration (GSA)
  Phone: (817) 978-2690

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
  Phone: (800) 363-3732
  www.eren.doe.gov/femp/procurement
- Green Seal certifies chillers that meet this recommendation's energy efficiency guidelines, as well as other environmental criteria.
  Phone: (202) 872-6400
  www.greenseal.org
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems, as well as a listing of chiller models that meet this Recommendation.
  Phone: (202) 429-0063
  aceee.org
- ASHRAE publishes the *Cooling and Heating Load Calculation Manual*.
  Phone: (800) 527-4723
  www.ashrae.org
- Air-Conditioning & Refrigeration Institute (ARI) publishes standards and directories for chillers and other air-conditioning equipment.
  Phone: (703) 524-8800
  www.ari.org
- E SOURCE publishes the *Electric Chillers Buyer's Guide*.
  Phone: (303) 440-8500
  www.esource.com
- Lawrence Berkeley National Laboratory's "Cool $ense" Web site has a variety of resources to help in combining building retofits with chiller replacements.
  eetd.lbl.gov/coolsense
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 484-0880

Why Agencies Should Buy Efficient Products

- *Executive Order 13123 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency, including all models that qualify for the EPA/DOE* ENERGY STAR® *product labeling program.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Efficiency Recommendation[a]

Product Type	Recommended		Best Available	
	Full-load[b] kW/ton	IPLV kW/ton	Full-load kW/ton	IPLV kW/ton
Centrifugal 150 – 299 tons	0.59 or less	0.52 or less	0.50	0.47
Centrifugal 300 – 2,000 tons	0.56 or less	0.44 or less	0.47	0.38
Rotary Screw ≥ 150 tons	0.64 or less	0.49 or less	0.58	0.46

a) The decision to specify chiller efficiency using full-load or IPLV should depend on the application. See "Buyer Tips," below, for further guidance.

b) Values are based on standard reference conditions, as specified in ARI Standard 550/590-98.

Definitions

Full-load efficiency is measured at peak load conditions as described in ARI Standard 550/590-98.

Integrated Part-Load Value (IPLV) is a weighted average of efficiency measurements at various part-load conditions, as described in ARI Standard 550/590-98. These weightings have changed substantially from the previous standard, ARI 550-92, lowering IPLV ratings by 10-15% for the same equipment.

Where to Find Energy-Efficient Chillers

The General Services Administration (GSA) has a Basic Ordering Agreement (BOA) which offers a streamlined procurement method for chillers based on lowest life-cycle cost. For more information, call GSA at the number listed (see "Federal Supply Source"). For chillers purchased through commercial sources, the BOA can still be used as a guide in preparing specifications, as can ARI and ASHRAE sources (see "For More Information").

An Energy Savings Performance Contract (ESPC) is an innovative method of financing a new chiller, as well as other associated energy conservation measures, with payments based on energy cost savings. For more information on ESPCs, call the FEMP Help Desk at (800) 363-3732.

Buyer Tips

The decision to specify chiller efficiency using full-load or part-load (IPLV) efficiency (kW/ton) levels depends upon the application. Full-load is appropriate where chiller loads are high and relatively constant (e.g., for "baseline" chillers); IPLV is preferred for more variable loads, the more common situation. To make the best selection, compare chiller options based on non-standard part load value (NPLV), which maintains the same weightings as IPLV, but allows the designer to prescribe other critical variables (such as entering condenser water temperature, evaporator leaving water temperature, flow rates, etc.). Proper determination of NPLV is described in ARI 550/590-98.

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were common in older chillers but are no longer used in new equipment. The 1992 signing of the Montreal Protocol banned the production of CFCs in the U.S., beginning in 1996. Much of today's equipment uses hydrochlorofluorocarbon (HCFC) refrigerants, which have a much lower ozone-depleting effect. There are also many energy-efficient chillers on the market that use hydrofluorocarbon (HFC) refrigerants, with no ozone-depleting effect. When purchasing an HCFC chiller, buyers can request that the manufacturer conduct leak testing before shipment; leakage of 1% annually is considered good for new equipment (consult Green Seal, listed in "For More Information").

Owners and operators of chillers with CFCs are faced with three options: 1) they can continue to operate their chillers with CFCs, which exposes them to the high cost of obtaining the refrigerant from a dwindling reclaimed supply; 2) they can convert the chillers to use a non-CFC refrigerant, which usually results in some loss in cooling capacity (see "Sizing," below); or 3) they can replace the equipment with a new chiller(s), which requires a substantial capital outlay. These options should be evaluated using life-cycle cost analysis (call the FEMP Help Desk at (800) 363-3732 to obtain LCC analysis materials). It is important when considering the continued operation of chillers with CFCs to assess the process of refrigerant recovery, followed by recycling or reclamation, and to factor in the likely substantial increase in the cost of obtaining replacement CFCs.

When retiring a chiller that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered on-site by a certified technician. For compliance information, contact the EPA Stratospheric Ozone Information Hotline at (800) 296-1996.

Early Replacement

Many facility managers are opting for early replacement of existing chillers with high efficiency units using non-CFC refrigerants. Good candidates for "early retirement" are CFC-based chillers with poor efficiencies or histories of high maintenance cost. Energy cost savings can add to the environmental benefits of non-CFC refrigerants. For example, replacing a 500-ton CFC chiller (0.85 kW/ton efficiency) with an efficient (0.56 kW/ton) non-CFC chiller can save $17,000/year, assuming a conservative 6¢/kWh. Demand charge savings may almost double this figure in some cases. In addition, many utilities offer financial incentives for efficient chiller replacements.

Sizing

When replacing a chiller, careful attention to appropriate sizing is critical to achieving maximum energy savings. Many existing units are oversized; an oversized chiller not only costs more to purchase, it also leads to substantial energy losses from excessive cycling. Use the referenced ASHRAE calculation procedure (see "For More Information") to properly determine the cooling load. It is often cost-effective to combine a chiller replacement with other measures to reduce cooling load, which permits specification of smaller equipment (see "Integrated Chiller Retrofits," below).

Replacing a single chiller with two or more smaller chillers to meet varying load requirements may be cost-effective. "Parallel staging" of multiple chillers is a common method of meeting peak load in larger installations. Multiple chillers also provide redundancy for routine maintenance and equipment failure. For many typical facilities, sizing one chiller at one-third and another chiller at two-thirds of the peak load enables the system to meet most cooling conditions at relatively high chiller part-load efficiencies. These staged units can also be sized optimally for different conditions. For example, one chiller could be optimized for peak efficiency at summer conditions (85^{o}F condensing water) and the other chiller could be optimized for winter conditions (75^{o}F condensing water).

Integrated Chiller Retrofits

An "integrated chiller retrofit" can provide enormous energy savings. It combines the chiller replacement, or a refrigerant change-out, with other energy conservation measures that reduce the cooling load or increase the efficiency of the cooling system itself. Examples of cooling system efficiency improvements are control system upgrades and increased cooling tower capacity. Cooling load reduction measures include tightening the building envelope, and lighting system retrofits. The additional cost of these and other load reduction measures can be significantly offset by the savings from the downsized chiller they make possible. Lawrence Berkeley National Laboratory's "Cool $ense" project provides guidance on integrated chiller retrofits (see "For More Information").

The first step in implementing an integrated chiller retrofit is a preliminary energy audit to assess the savings potential of various efficiency measures. A preliminary audit can often be provided by energy service companies, architecture and engineering firms, or utilities. FEMP can also provide this technical support, on a reimbursable sub-contract basis. For information, contact FEMP's Technical Assistance Team at (202) 586-1505.

Chiller Cost-Effectiveness Example

Centrifugal Chiller - 500 tons			
Performance	**Base Model[a]**	**Recommended Level**	**Best Available**
Full-Load Efficiency (kW/ton)	0.68	0.56	0.47
Annual Energy Use	680,000 kWh	560,000 kWh	470,000 kWh
Annual Energy Cost	$40,800	$33,600	$28,200
Lifetime Energy Cost	$595,000	$490,000	$410,000
Lifetime Energy Cost Savings	–	**$105,000**	**$185,000**
Rotary Screw Chiller - 250 tons			
IPLV Efficiency (kW/ton)	0.78	0.49	0.46
Annual Energy Use	390,000 kWh	245,000 kWh	230,000 kWh
Annual Energy Cost	$23,400	$14,700	$13,800
Lifetime Energy Cost	$340,000	$215,000	$200,000
Lifetime Energy Cost Savings	–	**$125,000**	**$140,000**

a) The efficiencies of the base models are just sufficient to meet ASHRAE Standard 90.1.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs, based on average usage and an assumed chiller life of 23 years. Future electricity price trends and a discount rate of 3.1% are based on federal guidelines (effective from April, 1999 to March, 2000).

Cost-Effectiveness Assumptions

Annual energy use for the centrifugal chiller example is based on 2,000 equivalent full-load hours per year for a 500 ton chiller. The rotary screw chiller example uses a 250 ton machine operating for 4,000 hours per year at 50% of rated load at part-load (IPLV) efficiencies, since rotary chillers are often installed in applications with variable load conditions. The assumed electricity price is 6¢/kWh, the federal average electricity price (including demand charges) in the U.S. Since this average cost figure does not incorporate the disproportionately large portion of demand costs that chillers usually contribute, the cost savings figures may be conservative.

Metric Conversion

1 ton (cooling capacity)
= 12,000 Btu/h
= 3.517 kW

Understanding the Cost-Effectiveness Table

In the first example shown above, a 500-ton centrifugal chiller with a full-load efficiency of 0.56 kW/ton is cost-effective if its purchase price is no more than $105,000 above the price of the Base Model. The Best Available centrifugal model, with an efficiency of 0.47 kW/ton, is cost-effective if its price is no more than $185,000 above the price of the Base Model. Similarly, in the second example, the 250-ton Recommended and Best Available rotary screw chillers are cost-effective if their respective purchase prices are no more than $125,000 and $140,000 above the price of the Base Model.

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How Do I Perform a Life-Cycle Cost Analysis for My Situation?

The basic formula for estimating a chiller's annual energy use multiplies the average system load (in tons) by the relevant efficiency (full-load or IPLV) by the annual number of equivalent full- or part-load operating hours. The resultant annual kWh figure can then be multiplied by the average cost per kWh for electricity, yielding the annual energy cost:

Annual Energy Cost = Avg. Load * Efficiency * Operating Hours * Electricity Rate.

For full life-cycle cost (LCC) analysis, this annual energy cost should then be multiplied by the regional electricity Uniform Present Value (UPV) factor for the estimated lifetime of the equipment, and then added to the initial cost of the chiller (or present value of the chiller's financed cost):

Life Cycle Cost = (Annual Energy Cost * Uniform Present Value Factor) + Initial Cost.

Definition

A Uniform Present Value factor is the multiplier that incorporates a discount rate, as well as any projected fuel or resource price changes, and allows the simple estimation of life-cycle costs or benefits (given a fixed annual cost or benefit figure and an expected product lifetime).

Note that this simplified formula excludes operation and maintenance costs, so does not represent a true life cycle cost calculation. However, when comparing chiller options that only differ in efficiency, where operation and maintenance costs are the same, it is permissible to exclude these estimated costs from the life-cycle cost analysis. A manual with the appropriate UPV factors ("Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis"), as well as an LCC analysis guidebook (NIST Handbook 135, "Life-Cycle Costing Manual for the Federal Energy Management Program") and LCC software (BLCC) are all available through the FEMP Help Desk, at (800) 363-3732.

A large proportion of chiller energy costs is often attributable to demand (kW) charges. To incorporate demand and ratchet charges into the cost estimation of chiller options, the ERATES software is also available from the FEMP Help Desk. Rate schedules from ERATES can be imported by the BLCC program, enabling much more accurate estimates of life-cycle costs.

FEMP provides a Web-based chiller "cost calculator" screening tool that simplifies the energy cost comparison between chillers with different efficiencies. Go to www.eren.doe.gov/femp/procurement/le_chiller.html, and click on the "Cost-Effectiveness Example."

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How to Buy an Energy-Efficient Commercial Unitary Air Conditioner

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Why Agencies Should Buy Efficient Products

- *Section 161 of the Energy Policy Act of 1992 (EPACT) encourages energy-efficient federal procurement. Executive Order 12902 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
  Phone: (800) 363-3732
  http://www.eren.doe.gov/femp/procurement
- Consortium for Energy Efficiency (CEE) provides information on utility programs promoting energy-efficient commercial air conditioners that meet this recommendation.
  Phone: (617) 589-3949
  http://www.ceeformt.org
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment,* which includes a chapter on HVAC systems, as well as a listing of air conditioner models that meet this Recommendation.
  Phone: (202) 429-0063
  http://aceee.org
- Air-Conditioning and Refrigeration Institute (ARI) publishes the *ARI Applied Directory* and the *ARI Unitary Directory,* which include monthly updated listings of commercial packaged air conditioners.
  Phone: (703) 534-8800
  http://www.ari.org
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) publishes the *Cooling and Heating Load Calculation Manual.*
  Phone: (800) 527-4723
  http://www.ashrae.org
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 484-0880

Efficiency Recommendation

Product Type[a] and Size	Recommended EER	Best Available EER
Air-Source 65 – 135 MBtu/h	10.3 or more	13.5
Air-Source 135 – 240 MBtu/h	9.7 or more	11.5
Air-Source > 240 MBtu/h	10.0 or more	11.7
Water-Source 65 – 135 MBtu/h	11.5 or more	12.5
Water-Source > 135 MBtu/h	11.0 or more	11.0

a) Electric air- and water-cooled split system and single package units with capacity over 65,000 Btuh are covered here. For smaller units, see "How to Buy an Energy-Efficient Residential Central Air Conditioner."

Definition

EER, or Energy Efficiency Ratio, is the cooling capacity (in Btu/hour) of the unit divided by its electrical input (in watts) at standard (ARI) conditions of 95^{o}F for air-cooled equipment, and 85^{o}F entering water for water-cooled models.

How to Select an Energy-Efficient Commercial Air Conditioner

DOE is working with the Defense Logistics Agency (DLA) and the General Services Administration (GSA) to identify products in the supply system that meet these Efficiency Recommendations, and to include additional energy-efficient products.

For a contractor-supplied air conditioner, specify an EER that meets the recommended level.

Sizing

Oversizing of air conditioners, besides raising purchase cost, will increase energy use, reduce humidity removal, and shorten product life, all due to excessive on-off cycling ("short-cycling"). The required air conditioner capacity should be determined based on the referenced ASHRAE calculation procedure (see "For More Information").

Heating Options

Commercial unitary air conditioners can usually be purchased with several options for heating, including a gas or oil furnace, hot water or steam coils, or electric resistance heating. Heat pump models are also available (see "How to Buy an Energy-Efficient Commercial Heat Pump"), and will always use less energy than electric resistance.

Technology Options

Water-source models, usually employing small cooling towers, are generally more efficient than air-source air conditioners, but their first cost and maintenance requirements are greater. In larger applications with multiple units, water-source models may be cost-effective, but cooling tower energy (pumps and fans) must be considered in the selection analysis.

Economizers use controllable dampers to provide "free" cooling by letting outside air cool the space when the outdoor temperature or enthalpy is below that of the building's return air. Economizers can decrease energy consumption substantially, but only if they are controlled and maintained properly, which they frequently are not.

Installation and Maintenance

Proper installation and maintenance of commercial packaged air conditioners is essential for effective and efficient operation. ACEEE's "Guide to Energy-Efficient Commercial Equipment" provides good guidance in this area (see "For More Information"). Duct losses are a major source of energy waste and comfort problems; make sure ducts are well-sealed.

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were used many years ago in commercial unitary air conditioners, but most equipment on the market today uses HCFC refrigerants, which have a much lower ozone-depleting effect. In the future, air conditioners with ozone-safe refrigerants are expected to be more widely available. When retiring an air conditioner that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered on-site by a certified technician. For compliance information, contact the EPA Stratospheric Ozone Information Hotline at (800) 296-1996.

Air Conditioner Cost-Effectiveness Example
(120 MBtu/hour – 10 tons)

Performance	Base Model[a]	Recommended Level	Best Available
Energy Efficiency Ratio (EER)	8.9	10.3	13.5
Annual Energy Use	20,200 kWh	17,500 kWh	13,300 kWh
Annual Energy Cost	$1,210	$1,050	$800
Lifetime Energy Cost	$12,200	$10,600	$8,100
Lifetime Energy Cost Savings	–	**$1,600**	**$4,100**

a) The efficiency (EER) of the Base Model is just sufficient to meet current U.S. DOE national appliance standards.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs based on average usage and an assumed air conditioner life of 15 years. Future electricity price trends and a discount rate of 4.1% are based on federal guidelines (effective from April, 1998 to March, 1999).

Cost-Effectiveness Assumptions

Annual energy use in this example is based on the standard DOE test procedure for a model with 1,500 equivalent full-load hours per year. The assumed electricity price is 6¢/kWh, the 1996 federal average electricity price in the U.S.

Using the Cost-Effectiveness Table

In the example shown above, an air conditioner with an EER of 10.3 is cost-effective if its purchase price is no more than $1,600 above the price of the Base Model. The Best Available model, with an EER of 13.5, is cost-effective if its price is no more than $4,100 above the price of the Base Model.

Metric Conversions

1MBtu/h = 1,000 Btu/h
= 293 Watts
*°F = (1.8 * °C) + 32*

What if my Electricity Price or Capacity is different?

To calculate Lifetime Energy Cost Savings for a different electricity price, multiply the savings in the above table by this ratio: $\left(\frac{\text{Your price in ¢/kWh}}{6.0\ \text{¢/kWh}}\right)$. If the capacity of your air conditioner differs, multiply the Lifetime Energy Cost Savings by: $\left(\frac{\text{Your capacity in tons}}{10\ \text{tons}}\right)$.

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Energy Efficiency and Renewable Energy
Federal Energy Management Program

How to Buy an Energy-Efficient Commercial Heat Pump

Why Agencies Should Buy Efficient Products

- *Section 161 of the Energy Policy Act of 1992 (EPACT) encourages energy-efficient federal procurement. Executive Order 12902 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Efficiency Recommendation

Product Type[a] and Size	Recommended		Best Available[b]	
	EER	COP	EER	COP
Air-Source 65 – 135 MBtu/h	10.1 or more	3.2 or more	11.7	3.5
Air-Source 135 – 240 MBtu/h	9.3 or more	3.1 or more	10.5	3.3
Water-Source 65 – 135 MBtu/h	13.0 or more	4.5 or more	15.0	5.0

a) Electric air- and water-cooled split system and single package units with capacity over 65,000 Btuh are covered here. For smaller units, see "How to Buy an Energy-Efficient Residential Air-Source Heat Pump."

b) The best available EER and best available COP may apply to different models.

Definitions

EER, or Energy Efficiency Ratio, is the cooling capacity (in Btu/hour) of the unit divided by its electrical input (in watts) at standard (ARI) conditions of 95°F for air-cooled equipment, and 85°F entering water for water-cooled models.

COP (Coefficient of Performance) is the heating capacity (in Btu) of the unit divided by its electrical input (also in Btu) at standard (ARI) conditions of 47°F dry bulb and 43°F wet bulb temperature for air-cooled equipment, and 70°F entering water for water-source models.

How to Select an Energy-Efficient Heat Pump

DOE is working with the Defense Logistics Agency (DLA) and the General Services Administration (GSA) to identify products in the supply system that meet these Efficiency Recommendations, and to include additional energy-efficient products.

For a contractor-supplied heat pump, specify an EER and COP that meet the recommended level.

When to Choose a Heat Pump

Heat pumps operate very inefficiently at sub-freezing temperatures, so should be avoided as stand-alone heating systems in cold climates. However, they will always offer energy savings over straight electric resistance heating coupled with an air conditioner. In climates with mild winters, heat pumps may provide cost-effective heating when compared with gas or oil furnaces, depending on relative utility costs.

Sizing

Oversizing of heat pumps, besides raising purchase cost, will increase energy use, reduce humidity removal, and shorten product life, all due to excessive on-off cycling

For More Information:

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  Phone: (800) 363-3732
  http://www.eren.doe.gov/femp/procurement
- Consortium for Energy Efficiency (CEE) provides information on utility programs promoting energy-efficient commercial heat pumps that meet this recommendation.
  Phone: (617) 589-3949
  http://www.ceeformt.org
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems, as well as a listing of heat pump models that meet this Recommendation.
  Phone: (202) 429-0063
  http://aceee.org
- Air-Conditioning and Refrigeration Institute (ARI) publishes the *ARI Applied Directory* and the *ARI Unitary Directory*, which include monthly updated listings of commercial packaged heat pumps.
  Phone: (703) 524-8800
  http://www.ari.org
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  Phone: (800) 527-4723
  http://www.ashrae.org
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 484-0880

("short-cycling"). The required heat pump capacity should be determined based on the referenced ASHRAE calculation procedure (see "For More Information").

Technology Options

Water-source models are generally more efficient than air-source heat pumps, especially in heating mode, but their first cost and maintenance requirements are greater. In larger applications with multiple units, water-source models may be cost-effective, but cooling tower energy (pumps and fans) must be considered in the selection analysis.

Economizers use controllable dampers to provide "free" cooling by letting outside air cool the space when the outdoor temperature or enthalpy is below that of the building's return air. Economizers can decrease energy consumption substantially, but only if they are controlled and maintained properly, which they frequently are not.

Installation and Maintenance

Proper installation and maintenance of commercial packaged heat pumps is essential for effective and efficient operation. ACEEE's "Guide to Energy-Efficient Commercial Equipment" provides good guidance in this area (see "For More Information"). Duct losses are a major source of energy waste and comfort problems with heat pumps; make sure ducts are well-sealed. Choosing and setting controls properly is also important to preventing energy losses; careful attention should be paid to minimizing operation of electric resistance heating.

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were used many years ago in heat pumps, but most equipment on the market today uses HCFC refrigerants, which have a much lower ozone-depleting effect. In the future, heat pumps with ozone-safe refrigerants are expected to be more widely available. When retiring a heat pump that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered on-site by a certified technician. For compliance information, contact the EPA Stratospheric Ozone Information Hotline at (800) 296-1996.

Heat Pump Cost-Effectiveness Example
(120 MBtu/hour – 10 tons)

Performance	Base Model[a]	Recommended Level	Best Available
EER / COP	8.9 / 3.0	10.1 / 3.2	11.7 / 3.5
Annual Energy Use	37,800 kWh	34,300 kWh	30,500 kWh
Annual Energy Cost	$2,300	$2,100	$1,800
Lifetime Energy Cost	$23,000	$21,000	$18,000
Lifetime Energy Cost Savings	–	**$2,000**	**$5,000**

a) The efficiency (EER and COP) of the Base Model is just sufficient to meet current U.S. DOE national appliance standards.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs based on average usage and an assumed heat pump life of 15 years. Future electricity price trends and a discount rate of 4.1% are based on federal guidelines (effective from April, 1998 to March, 1999).

Cost-Effectiveness Assumptions

Annual energy use in this example is based on the standard DOE test procedure for a model with 1,500 equivalent full-load heating and cooling hours per year. The assumed electricity price is 6¢/kWh, the 1996 federal average electricity price in the U.S.

Metric Conversions

1 MBtu/h = 1,000 Btu/h
= 293 Watts
*°F = (1.8 * °C) + 32*

Using the Cost-Effectiveness Table

In the example shown above, a heat pump with an EER of 10.1 and a COP of 3.2 is cost-effective if its purchase price is no more than $2,000 above the price of the Base Model. The Best Available model, with an EER of 11.7 and a COP of 3.5, is cost-effective if its price is no more than $5,000 above the price of the Base Model.

What if my Electricty Price, Capacity, or Load Hours are different?

Estimating Lifetime Energy Costs for different conditions can be difficult with heat pumps. For assistance, contact Lawrence Berkeley National Laboratory (see "For More Information").

FEMP FEDERAL ENERGY MANAGEMENT PROGRAM

How to Buy an Energy-Efficient Commercial Boiler

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Why Agencies Should Buy Efficient Products

- *Executive Order 13123 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency, including all models that qualify for the EPA/DOE* ENERGY STAR® *product labeling program.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Efficiency Recommendation[a]

Product Type (Fuel / Heat Medium)	Rated Capacity (Btu/h)	Recommended Thermal Efficiency	Best Available Thermal Efficiency[b]
Natural Gas / Water	300,000 - 2,500,000	80% E_t	86.7% E_t
	2,500,001 - 10,000,000	80% E_t	83.2% E_t
Natural Gas / Steam	300,000 - 2,500,000	79% E_t	81.9% E_t
	2,500,001 - 10,000,000	80% E_t	81.2% E_t
#2 Oil / Water	300,000 - 2,500,000	83% E_t	87.7% E_t
	2,500,001 - 10,000,000	83% E_t	85.5% E_t
#2 Oil / Steam	300,000 - 2,500,000	83% E_t	83.9% E_t
	2,500,001 - 10,000,000	83% E_t	84.2% E_t

a) This Recommendation covers low- and medium-pressure boilers used primarily in commercial space heating applications. It does not apply to high-pressure boilers used in industrial processing and cogeneration applications.

b) These "Best Available" efficiencies do not consider condensing boilers, which are generally more efficient, but are not readily ratable with ANSI Z21.13.

Definitions

Thermal efficiency (E_t), also known as "boiler efficiency" or "overall efficiency," is the boiler's energy output divided by energy input, as defined by ANSI Z21.13. In contrast to combustion efficiency (E_c), E_t accounts for radiation and convection losses through the boiler's shell.

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) is working, in conjunction with other groups, to develop a seasonal efficiency rating for boilers. This measure will account for varying efficiency at part-load operation. FEMP expects to adopt this rating method in the future once it is developed and sufficient product ratings are available.

How to Select Energy-Efficient Boilers

Specify boilers with efficiency levels that meet this Recommendation. Select only boilers rated under the certification program run by The Hydronics Institute (see "For More Information") of the Gas Appliances Manufacturers Association (GAMA). Although the HI directory reports only combustion efficiencies, thermal efficiencies can be calculated for model series listed **without** a pound sign by dividing gross output by input (using 140,000 Btu/gal. for #2 oil models).

Sizing and Part Load Performance

A boiler system should be capable of meeting the building's peak heating demand while also operating efficiently at the more common part-load conditions. Sizing and selecting a boiler system properly, therefore, requires a knowledge of the peak heating load, as well as an understanding of the

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
  Phone: (800) 363-3732
  www.eren.doe.gov/femp/procurement
- DOE's Office of Industrial Technologies' information clearinghouse provides publications on steam systems and helpful tips on improving boiler efficiencies.
  Phone: (800) 862-2086
  www.oit.doe.gov/
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems.
  Phone: (202) 429-0063
  aceee.org
- GAMA's Hydronics Institute publishes the *I=B=R Ratings for Boilers, Baseboard Radiation, and Finned Tube (Commercial) Radiation*, a directory of commercial boilers with certified performance ratings.
  Phone: (908) 464-8200
  www.gamanet.org
- ASHRAE publishes the *Cooling and Heating Load Calculation Manual*.
  Phone: (800) 527-4723
  www.ashrae.org
- American Boiler Manufacturers Association (ABMA) publishes a directory of commercial and industrial boiler manufacturers that offer equipment and services for boilers.
  Phone: (703) 5222-7350
  www.abma.com
- Boiler Efficiency Institute publishes maintenance and operating manuals on commercial and industrial boilers.
  Phone: (800) 669-6948
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 484-0880

load profile. If building loads are highly variable, as is common in commercial buildings, designers should consider installing multiple, smaller (modular) boilers. Modular systems are more efficient because they allow each boiler to operate at or close to full rated load most of the time, with reduced standby losses. Other efficient options for handling variable loads are modulating boilers, which can run at partial capacity (instead of cycling on and off), and condensing boilers.

While both water and steam models are covered in this Recommendation, water boilers and distribution systems tend to have lower maintenance requirements.

Buyer Tips

There is a broad array of options in boiler equipment and controls that can enhance energy performance: stack gas heat recovery equipment, such as air preheaters and economizers; condensing heat exchangers, which also utilize stack gas waste heat; turbulators (fin enhancers) to improve heat transfer and balance of gas flows between tube banks; water recovery equipment, to re-use heat from blowdown and water return condensate; outdoor temperature controls, which control the system loop temperature in accordance with outside temperatures; electronic ignition devices; increased boiler and piping insulation; and high performance (including "power") burners.

Maintenance and Operations Tips

Several diagnostic and preventive procedures are important to maintaining efficient operation. Flue gas temperature monitoring is useful in detecting efficiency and operation problems. Maintaining steady excess air levels (with an oxygen "trim" system) ensures that burners will mix air and fuel efficiently. The Boiler Efficiency Institute provides maintenance and operation manuals for boilers and boiler controls (see "For More Information"). Low water levels can damage boiler vessels, so water levels must be checked frequently. Water treatment prolongs the life of boilers, while increasing efficiency. Waterside and fireside surfaces should be cleaned annually. Steam boilers should be blowndown daily to remove sludge and sediment.

Boiler Cost-Effectiveness Example (5,000,000 Btu/h Gas-fired Water Boiler)

Performance	Base Model	Recommended Level	Best Available
Thermal Efficiency (Et)	78.0%	80.0%	83.2%
Annual Energy Use (therms)	96,200	93,700	90,100
Annual Energy Cost	$38,500	$37,500	$36,100
Lifetime Energy Cost	$646,000	$630,000	$606,000
Lifetime Energy Cost Savings	–	**$16,000**	**$40,000**

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs, based on average usage and an assumed boiler life of 25 years. Future gas price trends and a discount rate of 3.1% are based on federal guidelines (effective from April, 1999 to March, 2000).

Cost-Effectiveness Assumptions

Annual energy use in this example is based on 1,500 equivalent full-load hours per year. The assumed gas price is 40¢/therm, the federal average gas price in the U.S.

Conversions

1 Btu/h = 0.293 watts
1 therm = 100,000 Btu
= 100 MBtu
= 0.1 MMBtu

Understanding the Cost-Effectiveness Table

In the example shown above, a 5,000,000 Btu/h gas-fired water boiler with a thermal efficiency of 80.0% is cost-effective if its purchase price is no more than $16,000 above the price of the Base Model. The Best Available model, with an efficiency of 83.2%, is cost-effective if its price is no more than $40,000 above the price of the Base Model.

How Do I Perform a Life-Cycle Cost Analysis for My Situation?

FEMP provides a Web-based boiler "cost calculator." Go to www.eren.doe.gov/femp/procurement/boiler.html, and click on the "Cost-Effectiveness Example."

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Energy Efficiency and Renewable Energy
Federal Energy Management Program

How to Buy an Energy-Efficient Air-Cooled Electric Chiller

Why Agencies Should Buy Efficient Products

- *Executive Order 13123 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency, including all models that qualify for the EPA/DOE* ENERGY STAR® *product labeling program.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Efficiency Recommendation[a]

Compressor Type and Capacity	Recommended[b]		Best Available[b]	
	Full-load kW/ton	IPLV kW/ton	Full-load kW/ton	IPLV kW/ton
Scroll 30 – 60 tons	1.23 or less	0.86 or less	1.10	0.83
Reciprocating 30 – 150 tons	1.23 or less	0.90 or less	1.00	0.80
Screw 70 – 200 tons	1.23 or less	0.98 or less	0.94	0.83

a) The decision to specify chiller efficiency using full-load or IPLV should depend on the application. See "Buyer Tips," below, for further guidance.

b) Values are based on standard rating conditions, as specified in ARI Standard 550/590-98. Only packaged chillers (i.e., none with remote condensers) are covered.

Definitions

Full-load efficiency is measured at peak load conditions as described in ARI Standard 550/590-98.

Integrated Part-Load Value (IPLV) is a weighted average of efficiency measurements at various part-load conditions, as described in ARI Standard 550/590-98. These weightings have changed substantially from the previous standard, ARI 590-92, lowering IPLV ratings by 10-15% for the same equipment.

How to Select an Energy-Efficient Air-Cooled Chiller

When selecting an air-cooled chiller, specify an energy consumption rate (in kW/ton) that meets the recommended level for that compressor type. The Air Conditioning and Refrigeration Institute (ARI) lists manufacturers' catalogues and software with ARI-certified ratings in its *Applied Directory* (see "For More Information").

When to Choose an Air-Cooled Chiller

Upon deciding on a chilled water system, designers must choose between using air- or water-cooled chillers. Air-cooled systems eliminate the need for a cooling tower and its associated water pumps, piping, and fans, reducing installation and maintenance costs. However, air-cooled chillers are substantially less energy-efficient than water-cooled models (see "How to Buy an Energy-Efficient Water-Cooled Electric Chiller"). As system tonnage rises, the merits of choosing a water-cooled system increase. To compare air- and water-cooled options, a thorough life-cycle cost analysis can be performed using FEMP's "Building Life-Cycle Cost" (BLCC) software (see "For More Information").

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
  Phone: (800) 363-3732
  www.eren.doe.gov/femp/procurement
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems, as well as a listing of chiller models that meet this Recommendation.
  Phone: (202) 429-0063
  aceee.org
- ASHRAE publishes the *Cooling and Heating Load Calculation Manual*.
  Phone: (800) 527-4723
  www.ashrae.org
- Air-Conditioning & Refrigeration Institute (ARI) publishes the *Applied Directory*, which lists manufacturers' catalogues and software with ARI-certified capacity and efficiency ratings. This information is also available through ARI's on-line directory, "Prime Net."
  Phone: (703) 524-8800
  www.ari.org
- E SOURCE publishes the *Electric Chillers Buyer's Guide*.
  Phone: (303) 440-8500
  www.esource.com
- Lawrence Berkeley National Laboratory's "Cool $ense" Web site has a variety of resources to help in combining building retrofits with chiller replacements.
  ateam.lbl.gov/coolsense
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
  Phone: (202) 646-7950

Buyer Tips

The decision to specify chiller efficiency using full-load or part-load (IPLV) efficiency (kW/ton) levels depends upon the application. IPLV is preferred for more variable loads, a situation much more common in air-cooled chiller applications.

Maintenance costs for air-cooled chillers vary by compressor type. Screw and scroll compressor models generally cost more initially, but can operate longer before overhauling.

Sizing

When selecting a chiller, careful attention to appropriate sizing is critical to minimize energy use. An oversized chiller not only costs more to purchase, but also leads to substantial energy losses from poor low-load performance and excessive cycling. Use the referenced ASHRAE calculation procedure (see "For More Information") to properly determine the cooling load. It is often cost-effective to combine a chiller replacement with other measures that reduce cooling load, permitting specification of smaller capacity chillers (see the "Cool $ense" Web site listed in "For More Information").

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were common in older chillers but are not used today. The 1992 signing of the Montreal Protocol banned the production of CFCs in the U.S., beginning in 1996. Most air-cooled equipment sold today uses hydrochlorofluorocarbon (HCFC) refrigerants, which have a much lower ozone-depleting effect. When retiring a chiller that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered on-site by a certified technician. For compliance information, contact the EPA Stratospheric Ozone Information Hotline at (800) 296-1996.

Noise pollution can be a substantial issue with air-cooled chillers. Rotary screw and scroll compressor models are generally considerably quieter than reciprocating models.

Chiller Cost-Effectiveness Example
100-ton Screw Chiller

Performance	Base Model[a]	Recommended Level	Best Available
IPLV Efficiency (kW/ton)	1.25	0.98	0.83
Annual Energy Use	250,000 kWh	196,000 kWh	166,000 kWh
Annual Energy Cost	$15,000	$11,800	$10,000
Lifetime Energy Cost	$219,000	$172,000	$145,000
Lifetime Energy Cost Savings	–	*$47,000*	*$74,000*

a) The efficiency of the base model is just sufficient to meet ASHRAE Standard 90.1-99.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs, based on average usage and an assumed chiller life of 23 years. Future electricity price trends and a discount rate of 3.4% are based on federal guidelines (effective from April, 2000 to March, 2001).

Cost-Effectiveness Assumptions

Annual energy use is based on 2,000 equivalent full-load hours per year. IPLV efficiencies are compared, since air-cooled chillers are generally installed in applications with highly variable load conditions. The assumed electricity price is 6¢/kWh, the federal average electricity price (including demand charges) in the U.S. Since this average cost figure does not incorporate the disproportionately large portion of demand costs that chillers usually contribute, the cost savings figures may be conservative.

Metric Conversion

1 ton (cooling capacity)
= 12,000 Btu/h
= 3.517 kW

Understanding the Cost-Effectiveness Table

In the example shown above, a 100-ton air-cooled screw chiller with an IPLV efficiency rating of 0.98 kW/ton is cost-effective if its purchase price is no more than $47,000 above the price of the Base Model. The Best Available screw model, with an efficiency of 0.83 kW/ton, is cost-effective if its price is no more than $74,000 above the price of the Base Model.

FEMP provides a Web-based "cost calculator" screening tool that simplifies the energy cost comparison between different air-cooled chillers. Go to www.eren.doe.gov/femp/procurement/air_chiller.html, and click on the "Cost-Effectiveness Example."

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